A Training Manual for Training of Trainers on Irrigation Water Management for Vegetable and Fruit Crops Production

Volume 2

By

Tilahun Hordofa (PhD)
Gobena Dirirsa

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Irrigation Water Management for Vegetable and Fruit Crops Production

Tilahun Hordofa, Email: tilahun_hordofa@yahoo.com; Cellphone: 0911842492
Ethiopian Institute of Agricultural Research, Melkassa Agricultural Research Center,
P.O. Box 436, Tel. 251-022 2250210, Fax: 251-022225 0213

1. Introduction

The main objective of irrigation is to provide plants with sufficient water to prevent stress that may cause reduced yield or poor quality of harvest. Too much water is not good for many crops. Apart from paddy rice, there are only very few crops which like to grow "with their feet in the water". If there is too much water in the soil there will not be enough air. The excess water must be removed. If there is too little water in the soil, it must be supplied from other sources. Therefore, adequate water supply is important for plant growth,

The process by which irrigation water is controlled and used in the agricultural production is called Irrigation Water Management, IWM.

2. Land Grading and Layout

Any lined used for agriculture requires an even surface for crop production. Land grading consists in reshaping the field surface to a desired grade. Land grading is beneficial both under irrigated and rainfed condition. Land grading removes humps and depressions interfering with the flow of water on the land surface. Low spots could cause concentration of water and waterlogging which may after crop growth, and may also bring harmful salts to the surface.

Land grading in irrigated agriculture helps in uniform application of water, better water regulation and saving in irrigation time. Either in irrigated agriculture or under rainfed condition land grading provides the much-needed surface drainage.

Field layout is important both in water management and use of machinery. Due to land fragmentation, a proper layout may be difficult. Land consolidation and proper layout will improve land and labor productivity. The land grading operations required for an area depend upon the topography of the area, soil type, soil depth, crops to be grown, source of water supply and method of irrigation. Based on the initial topography of the land, the layout of the individual fields, irrigation and drainage system are need to be planned. The individual fields should be leveled subsequently as per their requirement.

Figure 1. Laser land leveling

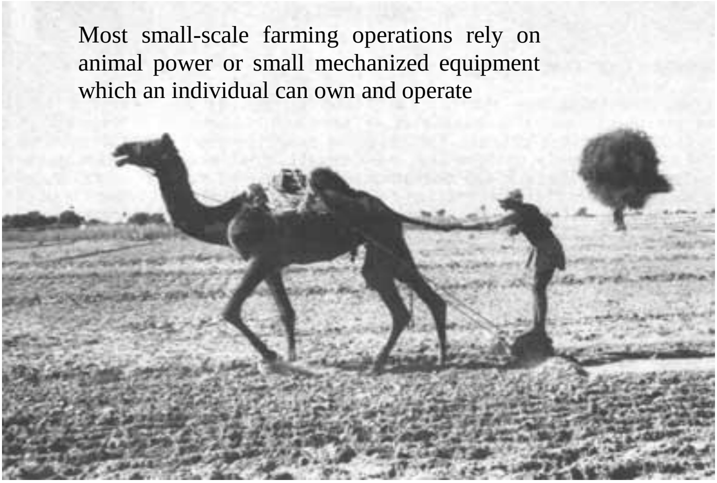


Figure 2. Land levelinzg using animal power

3. Measurement of Soil Moisture

There are two general reasons for measuring soil water/ moisture. One is to determine the moisture content of a soil. This information is necessary to calculate the water needed to restore the soil water in the root zone of the crop. The second reason is to determine the soil-water potential. Knowledge of the soil water potential may also indicate when to irrigate.

Two methods:

A. Direct method, and
B. Indirect method

A. Direct method

Oven dry method/ *Gravimetric water content determination method*

One of the commonest methods of determining soil moisture content is the oven-dry method. It consists of taking a soil sample of approximately 200 grams, determining its exact weight, and drying the sample in an oven at a temperature of 105 centigrade for 24 hours, then weighing the sample and determining the moisture loss by subtracting the oven-dry weight from the moist weight.

Moisture content is expressed as a percentage of the oven-dry weight of the soil (SMC%wt.):

$$SMC(\%wt) = \frac{\text{weight of wet soil (gm)} - \text{weight of dry soil (gm)}}{\text{Weight of dry soil (gm)}} \times 100$$

Soil moisture depleted between irrigation computed from:

$$IRn = (FC - MC) * BD * drz$$

where IRn is the net water depleted (mm); FC is the soil water content at field capacity (%weight); MC is the soil water content measured at any time (%weight); BD is the soil bulk density (g/cm3) and root zone/sampling depth (mm)

Although simple and reliable, it is a destructive and time-consuming technique. The data are also at least one day old when made available for use

B. Indirect method

Different soil moisture measuring device will be used to measure the in-situ available soil moisture. Soil moisture data will be made available for immediate use. Some of the instruments used for measuring the in-situ soil moisture include:

- Porous/ Gypsum block meter
- Neutron probe
- TDR
- Aquaterr
- Tensiometer
- Divinor 2000

Gypsum-block method

The electrical properties of conductance or resistance can be used to indicate the moisture content of soils. The electrical properties of soils change when moisture content changes

Porous blocks of gypsum containing electrical elements are placed in the soil (Fig. 3). The moisture content of the blocks changes as the soil moisture content changes. As the moisture increases, the amount of gypsum in solution increases and the resistance between electrical elements in the block decreases. Therefore, the more water in the soil is the lower the resistance.

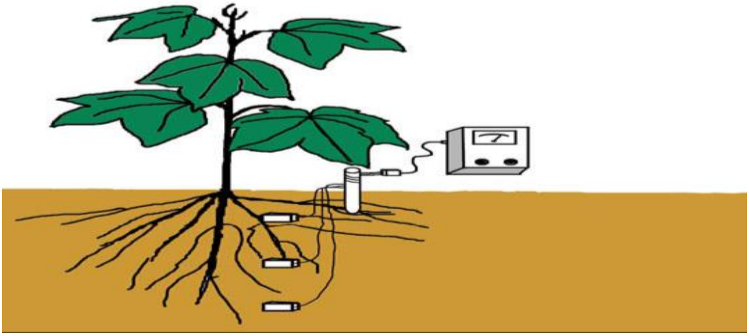


Figure 3. Three Resistance blocks installed in the field

To measure soil moisture, the blocks are buried in the ground at the desired depth, with wire leads to the soil surface. A meter is connected to the wire leads and a reading is taken. The interpretation of the reading is given in Table 1

Materials such as fiber glass and nylon have also been used for making blocks. Gypsum blocks operate best at tensions between 1 and 15 atmospheres, while nylon blocks are more sensitive and function best at tensions less than two atmospheres. Because of their volubility, gypsum blocks deteriorate in one to three seasons. Gypsum blocks are less sensitive than nylon and fiber glass blocks to soil salts.

Table 1. Interpretation of Readings on Electrical Resistance Meters as Related to Soil Water Tension

Soil moisture condition	Bars Tension	Meter Readings*	Interpretation
Nearly saturated	less than 0.05	0 to 5	Near saturated soil. Occurs for a few hours following a rain/irrigation.
Field capacity	0.10 to 0.20	5 to 20	Field capacity. Irrigations discontinued in this range.
Irrigation range	0.20 to 0.60	20 to 60	Usual range for starting irrigation. Starting irrigation in this range insures maintaining readily available soil moisture at all times
Dry	greater than 0.60	more than 60	Stress range for most soils and crops. Some soil moisture present but dangerously low for maximum plant growth and production

* These readings will vary according to meter type and soil type.

Tensiometer

A Tensiometer is a sealed, water-filled tube with a porous ceramic tip on the lower end and a vacuum gauge on the upper end (Fig. 4). The tube is installed in the soil with the ceramic tip placed at the desired root zone depth and with the gauge above ground. As soil dries out, the soil particles retain the water with greater force. Tensiometer measure how tightly the soil water is being held. The interpretation of the reading is given in Table 2. In dry soil, water is drawn out of the instrument, reducing the water volume in the tube and creating a partial vacuum which is registered on the gauge. The drier the soil, the higher is the reading.

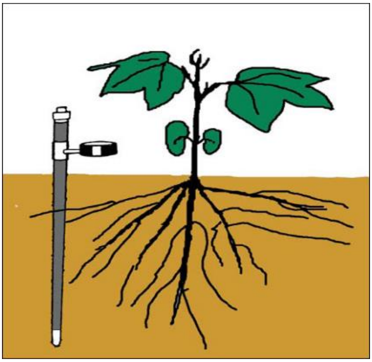


Figure 4. Tensiometer installed in the field

When the soil receives water through rainfall or irrigation the action is reversed. The vacuum inside the tube draws water from the soil back into the instrument which in turn results in lower gauge readings. Tensiometer work well in soils with high soil-water content, but tend to lose good soil contact when the soil becomes too dry

Table 2. The interpretation of the Tensiometer reading

Reading (in Centibar)	Interpretation
0	Very wet – Saturated
10 – 25	Favorable moisture and aeration condition
25 – 40	It is required to irrigate for most sensitive plants with shallow root system and light soils
40 – 50	It is required to provide irrigation for plants with moderate water needs
50 – 70	It is required to provide irrigation for plants with deep rooted system growing on moderate soils – in case of heavier soils, one can start irrigation later when the gauge reading is about to reach the value of 70 centibars. Beyond 70 is stress range
80	Relatively dry soil

Neutron probe

A neutron probe is a device used to measure the quantity of water present in soil. The neutron probe has been used extensively in research to determine soil moisture. A neutron probe contains a radioactive source that sends out fast neutrons. When fast neutrons hit a hydrogen atom, they slow down. A detector within the probe measures the rate of fast neutrons leaving and slow neutrons returning. This ratio can then be used to estimate soil moisture content. However, because every soil has some background hydrogen sources that are not related to water, calibration is important for each soil. To measure soil moisture with a neutron probe, an access tube is installed into the ground. Then, the probe (which contains the radioactive source and the detector) is lowered to the desired depth (Fig. 5.).

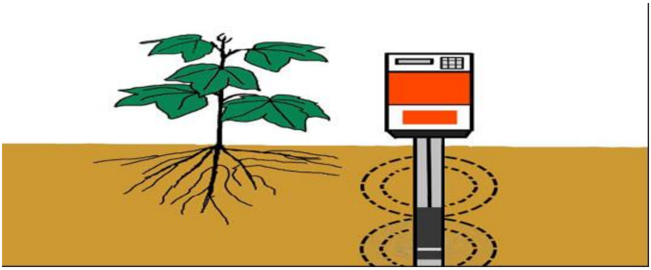


Figure 5. A Neutron probe measuring soil moisture in the field

Feel method

Feel method involves estimating soil-water by feeling the soil. Determining soil moisture by feeling the soil has been used for many years by researchers and growers alike. By squeezing the soil between the thumb and forefinger or by squeezing the soil in the palm of a hand, a fairly accurate estimate of soil moisture can be determined (Fig. 6). A soil probe is used to sample the soil profile. Soil moisture is evaluated by feeling the soil. Then a chart is used to judge relative moisture levels. It is important to sample numerous locations throughout the field as well as several depths in the soil profile. It takes a bit of time and some experience, but it is a proven method. Table 3 gives a description of "how the soil should feel" at certain soil moisture levels.

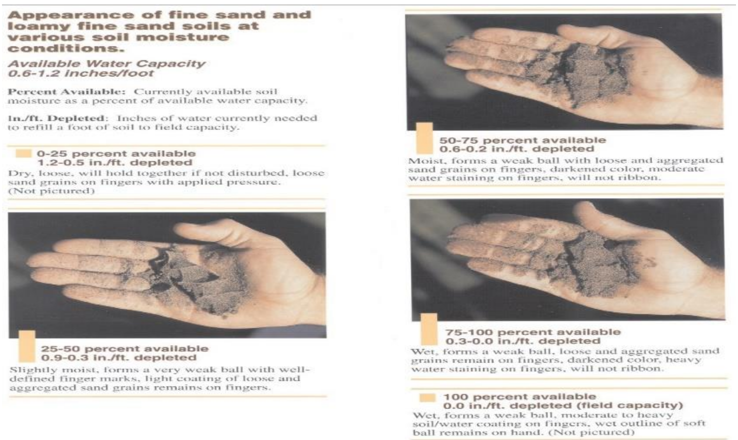


Figure 6. Soil moisture determination by feeling

Table 3. Guide for judging how much of available moisture has been removed from the soil

Depletion of Available Soil Moisture in %	Feel or appearance of soil and moisture deficiency in centimeters of water per water of soil Coarse texture Moderately coarse Medium texture Fine & very fine texture			
0 (Filed capacity)	Upon squeezing, no free water appears on soil but wet outline of bell is left on hand	Upon squeezing free water appears on soil but wet outline of ball is left on hand	Upon squeezing, no free water appears on soil but wet outline of ball is left on hand	Upon squeezing, no free water appears on soil but wet outlying of ball is left on hand
0 – 25	Tends to stick together slightly, sometimes forms a very weak ball under pr	Forms week ball, breaks easily, will not slick	Forms a ball, is very pliable, slicks readily if relatively high in clay	Easily ribbons out between fingers, has slick feeling
25-50	Appears to be dry, will not form a ball with pressure	Tends to ball under pressure but seldom holds together	Forms a ball somewhat plastic, will slick slightly with pressure	Forms a ball, ribbons or between thumb and fore-finger
50-75	Appears to be dry, will not form a ball with pressure	Appears to be dry, will not form a ball	Somewhat crumbly but holds together from pressure	Somewhat pliable, will ball under pressure
75-100 (100 percent is permanent wilting point)	Dry, loose single grained, flows through fingers	Dry, loose, flows through fingers	Powdery, dry, sometimes slightly crusted but easily broken down into powdery condition	Hard, baked, cracked, sometimes has loose crumbs on surface

4. Irrigation Water Application Methods

Various methods can be used to supply irrigation water to the plants. Each method has its advantages and disadvantages. These should be considered when choosing the method which is best suited to the local circumstances. A simple irrigation method is to bring water from the source of supply, e.g. a well, to each plant with a bucket or a watering can.

This can be a very time-consuming method and involves very heavy work. However, it can be used successfully to irrigate very small plots of land, such as vegetable gardens, that are close to the water source.

More sophisticated methods of water application are used when larger areas require irrigation. There are three commonly used methods: surface irrigation, sprinkler irrigation and drip irrigation.

4.1. Surface Irrigation

Surface irrigation systems are based on the principle of moving water over the surface of the land in order to wet it, either partially or completely. They can be subdivided into furrow, border strip and basin irrigation. The scheme layout up to field level, such as canals and drains, can be similar for each system. Low irrigation efficiencies are usually associated with poor land leveling, wrong stream size and change in soil type along the irrigated area both vertically and horizontally.

4.1.1. Furrow irrigation

Furrows are small channels, which carry water down the land slope between the crop rows. Water infiltrates into the soil as it moves along the slope. The crop is usually grown on the ridges between the furrows. This method is suitable for all row crops and for crops that cannot stand in water for long periods (e.g. 12-24 hours).

Furrow irrigation is suitable for a wide range of soil types, crops and land slopes. Crops, especially row crops. Crops that would be damaged if water covered their stem or crown should be irrigated by furrows.

A furrow irrigation system consists of furrows and ridges, of which the shape, spacing and length depend mainly on the crops to be grown and the types of soils (Fig. 7).

The width of the furrows varies from 25-40 cm, the depth from 15-30 mm and the spacing between the furrows from 0.75-1.0 m, depending on soil type, crops and stream size to be applied to the furrow. Coarse soils require closely-spaced furrows in order to achieve lateral water flow in the root zone. Figure 8 show the general wetting patterns of sand and clay. There is more lateral water flow in clay than in sand. Typical furrow lengths vary from about 60 m on coarse textured soils to 500 m on fine textured soils, depending on the land slope, stream size and irrigation depth. The minimum and maximum slopes for furrows should be 0.05% and 2% respectively in areas of low rainfall intensity. In areas where there is a risk of erosion due to intensive rainfall, the maximum slope should be limited to 0.3%.

Figure 7. Furrow irrigation system using syphon

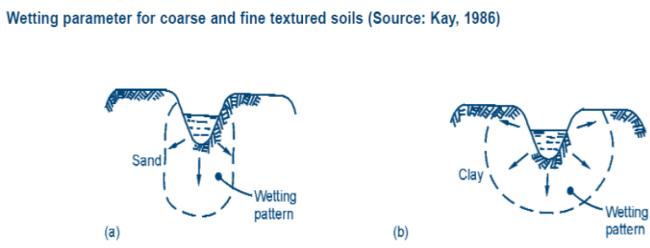


Figure 8. Wetting patter under sandy and clay soil

Table 4. Furrow length related to furrow slope, stream size, soil type and irrigation depth

	Soil type	Clay		Loam			Sand		
		Average irrigation depth (mm)							
Furrow slope %`	Maximum stream size (l/sec)	75	150	50	100	150	50	75	100
0.05	3.0	300	400	120	270	400	60	90	150
0.10	3.0	340	440	180	340	440	90	120	190
0.20	2.5	370	470	220	370	470	120	190	250
0.30	2.0	400	500	280	400	500	150	220	280
0.50	1.2	400	500	280	370	470	120	190	250
1.00	0.6	280	400	250	300	370	90	150	220
1.50	0.5	250	340	220	280	340	80	120	190
2.00	0.3	220	270	180	250	300	60	90	150

4.1.2. Border irrigation

Borders are long, sloping strips of land separated by bunds. They are sometimes called border strips. Irrigation water can be fed to the border in several ways: opening up the channel bank, using small outlets or gates or by means of siphons. A sheet of water flows down the slope of the border, guided by the bunds on either side. A horizontal cross-section facilitates an even rate of water advance down the longitudinal slope. Border strips can vary from 3-30 m in width and from 60-800 m in length. They are separated by parallel dykes or border ridges (levées).

Border irrigation is generally best suited to the larger mechanized farms as it is designed to produce long uninterrupted field lengths for ease of machine operations. Borders can be up to 800 m or more in length and 3-30 m wide depending on a variety of factors. It is less suited to small-scale farms involving hand labor or animal-powered cultivation methods. Deep homogenous loam or clay soils with medium infiltration rates are preferred. Heavy, clay soils can be difficult to irrigate with border irrigation because of the time needed to infiltrate sufficient water into the soil. Basin irrigation is preferable in such circumstances. Close growing crops such as pasture or alfalfa are preferred.

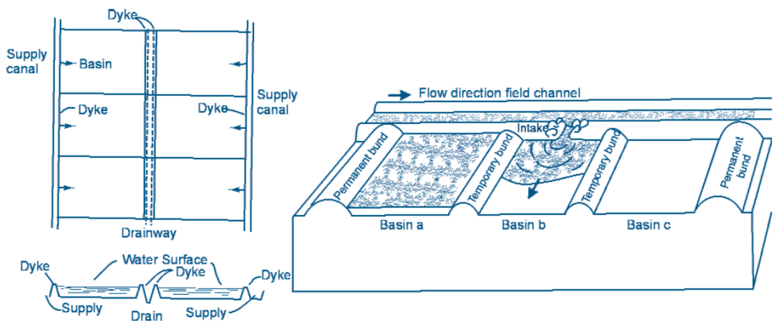
Figure 9. Border irrigation system using syphon

Table 5. Border strip widths and lengths for smallholder irrigation schemes

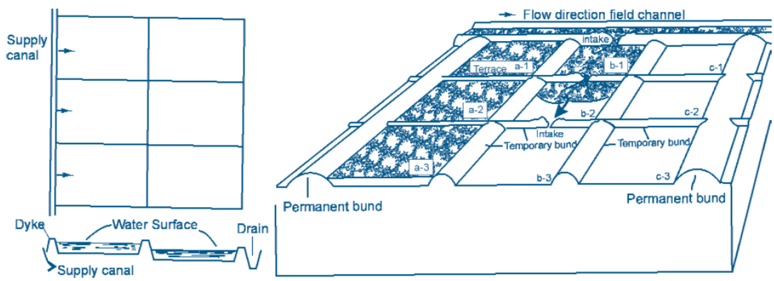
Soil type	Borderstrip slope (%)	Unit flow per metre width* (l/sec)	Borderstrip width (m)	Borderstrip length (m)
Sand (Infiltration rate greater than 25 mm/h)	0.2-0.4 0.4-0.6 0.6-1.0	10-15 8-10 5-8	12-30 9-12 6-9	60-90 80-90 75
Loam (Infiltration rate of 10 to 25 mm/h)	0.2-0.4 0.4-0.6 0.6-1.0	5-7 4.6 2-4	12-30 9-12 6	90-250 90-180 90
Clay (Infiltration rate less than 10 mm/h)	0.2-0.4 0.4-0.6 0.6-1.0	3-4 2-3 1-2	12-30 6-12 6	180-300 90-180 90

4.1.3. Basin irrigation

Basins are flat areas of land, surrounded by low bunds. The bunds prevent the water from flowing to the adjacent fields. Basin irrigation is commonly used for rice grown on flat lands or in terraces on hillsides (Fig. 11). The basin method is suitable for crops that are unaffected by standing in water for long periods. Other crops which are suited to basin irrigation include: pastures, e.g. alfalfa, clover; trees, e.g. citrus, banana; crops which are broadcast, such as cereals; to some extent row crops such as tobacco. Basin irrigation is generally not suited to crops which cannot stand in wet or waterlogged conditions for periods longer than 24 hours. These are usually root and tuber crops such as potatoes, cassava, beet and carrots which require loose, well-drained soils.



Direct method of water supply to the basins with a drainway midway between supply canals. “Basin a” is irrigated, then “Basin b”, and so on.



Cascade method of water supply to the basins with a tier arrangement. Ideal on terraced land, where water is supplied to the highest terrace, and then allowed to flow to a lower terrance and so on.

Figure 10. Layout of basin irrigation

Figure 11. Basin irrigation system for close growing crops

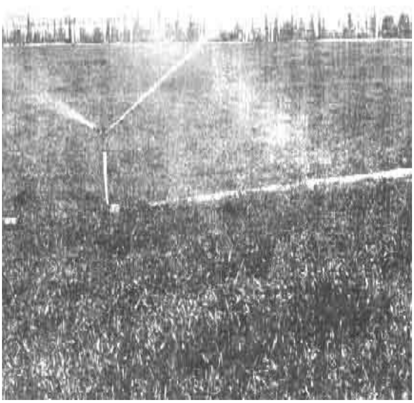
Table 6. Basin area in m^2 for different stream sizes and soil types

Stream size (l/sec)	Sand	Sandy loam	Clay loam	Clay
5	35	100	200	350
10	65	200	400	650
15	100	300	600	1 000
30	200	600	1 200	2 000
60	400	1 200	2 400	4 000
90	600	1 800	3 600	6 000

4.2. Sprinkler Irrigation

Sprinkler irrigation is similar to natural rainfall (Fig. 12). Water is pumped through a pipe system and then sprayed into the air through rotating sprinkler heads so that it breaks up into small water drops which fall to the ground. Sprinkler irrigation is suited for most row, field and tree crops and water can be sprayed over or under the crop canopy. However, large sprinklers are not recommended for irrigation of delicate crops such as lettuce because the large water drops produced by the sprinklers may damage the crop.

Sprinkler irrigation is adaptable to any farmable slope, whether uniform or undulating. Sprinklers are best suited to sandy soils with high infiltration rates although they are adaptable to most soils. The average application rate from the sprinklers (in mm/hour) is always chosen to be less than the basic infiltration rate of the soil so that surface ponding and runoff can be avoided. Sprinklers are not suitable for soils which easily form a crust.



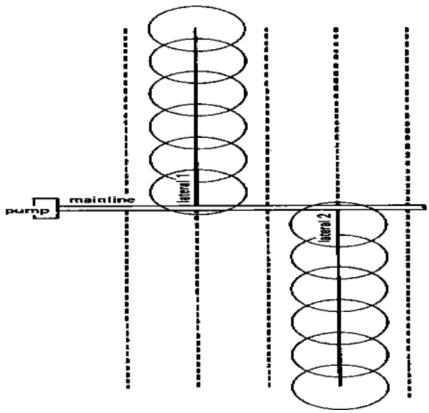


Figure 12. Different system of sprinkler irrigation

Table 7. Farm irrigation efficiencies for sprinkler irrigation in different climates

Climate	Farm Irrigation Efficiency
Cool	80%
Moderate	75%
Hot	70%
Desert	65%

It should be pointed out that in order to avoid runoff; the sprinkler application rate should not exceed the basic soil infiltration rate (Table 8). Hence, the basic infiltration rate of the soil is used as a guide to select a sprinkler with a precipitation rate lower than the infiltration rate.

Table 8. Typical basic soil infiltration rates

Soil type	Basic infiltration (mm/hr)
Clay	1 - 7
Clay Loam	7 - 15
Silt Loam	15 - 25
Sandy Loam	25 - 40
Sand	>40

4.3. Drip Irrigation

Drip irrigation is slow application of water to the soil through mechanical device called emitters located at selected points along the water delivery line called laterals. With drip irrigation, water is conveyed under pressure through a pipe system to the fields, where it drips slowly onto the soil through emitters or drippers which are located close to the plants. Only the immediate root zone of each plant is wetted. Therefore, this can be a very efficient method of irrigation. Drip irrigation is sometimes called trickle irrigation (Fig. 13 and 14).

Drip irrigation is most suitable for row crops (vegetables, soft fruit), tree and vine crops where one or more emitters can be provided for each plant. Generally, only high value crops are considered because of the high capital costs of installing a drip system. Drip irrigation is adaptable to any farmable slope. Normally the crop would be planted along contour lines and the water supply pipes (laterals) would be laid along the contour also. This is done to minimize changes in emitter discharge as a result of land elevation changes.

Drip irrigation is suitable for most soils. On clay soils water must be applied slowly to avoid surface water ponding and runoff. On sandy soils higher emitter discharge rates will be needed to ensure adequate lateral wetting of the soil.

One of the main problems with drip irrigation is blockage of the emitters. All emitters have very small waterways ranging from 0.2-2.0 mm in diameter and these can become blocked if the water is not clean. Thus, it is essential for irrigation water to be free of sediments. If this is not so then filtration of the irrigation water will be needed. Blockage may also occur if the water contains algae, fertilizer deposits and dissolved chemicals which precipitate such as calcium and iron. Filtration may remove some of the materials but the problem may be complex to solve and requires an experienced engineer or consultation with the equipment dealer.

Drip irrigation is particularly suitable for water of poor quality (saline water). Dripping water to individual plants also means that the method can be very efficient in water use. For this reason, it is most suitable when water is scarce.

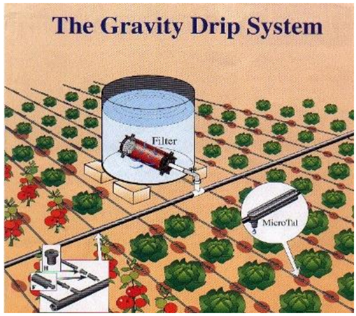


Figure 13. Gravity drip irrigation system

Figure 14. Pressurized drip irrigation system

Choice of emitter:

- Flow rate (0.2 - 8 l/h)
- **Diameter** of lateral line (8 12 16 20 mm)

- Spacing of emitter (0.25 0.30 0.40 0.50 0.60 0.80 1.00 1.25 1.50 m)
- Number of lines per bed (1 2 3 4)

The decision to choose depends:

- Soil type
- Root zone depth
- Plant density
- Crop water requirement
- Agro meteorology
- Limits of the manifold and system
- Investment capacity and justification

Different type of emitters/ Drippers

On-line emitters are punched on lateral lines at desired spacing

In-line emitters

In-line emitters are factory made and ordered by desired emitter spacing

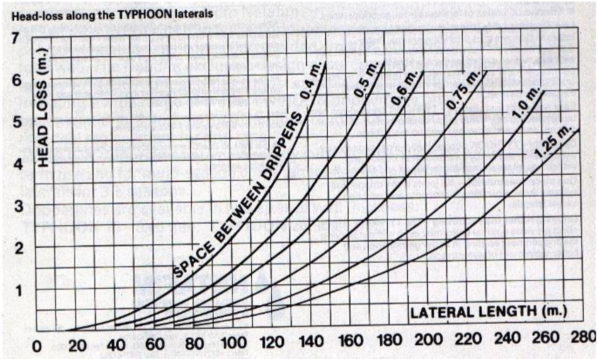


Figure 15. Length of a lateral, spacing and head loss

5. DRAINAGE

Drainage is the removal of water in excess of the quantity required for the crop. Drainage includes removal of excess surface and subsurface water in the root zone. Irrigation and drainage go together and are not mutually exclusive. Irrigation system aims at supplying optimal quantities of water throughout the crop period. Drainage system aims at removing excess quantity of water in short time. Often both may be required together to remove sustained and high-level production of crops. Excess water causes great harm to the crop by reducing availability of oxygen to the root system and accumulating carbon dioxide and other gasses harmful to the root system. Drainage of excess water from irrigated fields is necessary for satisfactory growth and yield of crops. Generally, irrigation is a very difficult task that may result in very low application efficiencies, drainage problems and waterlogging.

5.1. Drainage System

There are two general types of land drainage systems: (1) Surface drainage which removes excess surface water from the farm field (Fig. 16), and (2) sub-surface drainage which removes excess water from the crop root zone depth of the soil.

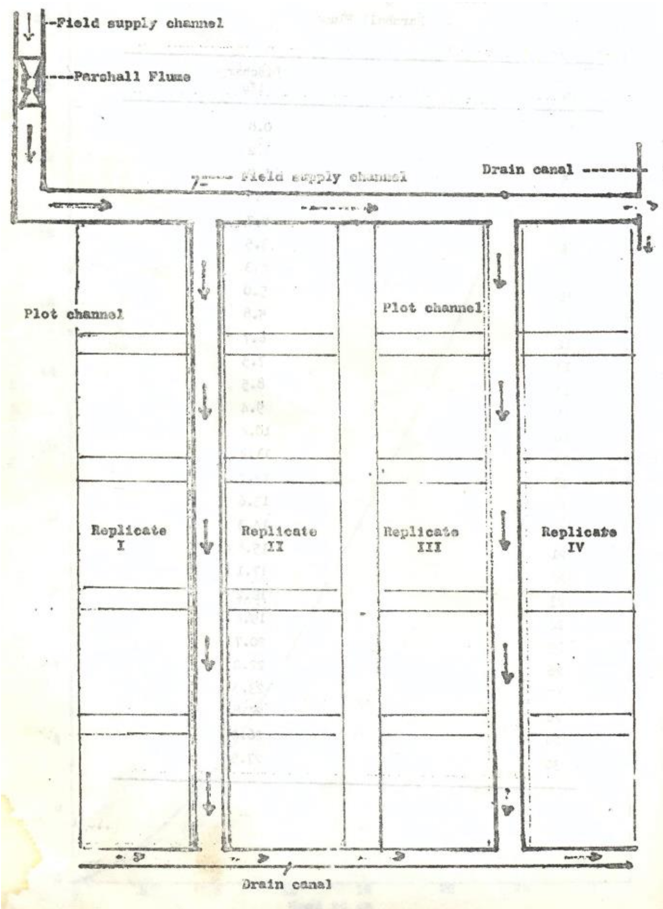


Figure 16. Typical irrigated and drainage system field layout

5.2. Effects of Waterlogging

Waterlogging is generally defined as the condition where water table is less than 3m from the surface. At this depth, water from the water tables rises at significantly rapid rates by capillary action to the ground surface. The following are effects of waterlogging.

(1) Waterlogging reduces soil aeration. This results in reduction of oxygen supply to the root system of the plant. There is also a buildup of carbon dioxide, methane, ethane and profane in the soil, which is harmful to the root system. Root damage is the final result of prolonged waterlogging. Oxygen concentration in the soil atmosphere is about 17-20% and when it falls to less than 10% due to displacement of air in the soil pores by water, growth of the plant the plant is inhibited.
(2) Due to anaerobic condition in the root zone, uptake of nutrients is affected.
(3) Due to restriction of root growth the volume of soil tapped by the plant roots nutrients is restricted.

5.3. Remedial Measures

Remedial measures adopted in surface flooded areas (due to inundation by floods) includes channel improvement, structures to prevent entry of flood waters into cultivated areas, embankments, detention dams ,anti-erosion schemes ,detention basins ,diversion of flood waters, watershed management, sea wall etc., In the case of drainage congestion in irrigated areas, measures adopted include surface drainage ,lining of canals to prevent seepage ,sinking of tube wells to depress the ground water table etc.

5.4. Benefits of Drainage

Draining the land provides conditions favorable for high crops Production. The greatest benefits of drainage relate to aeration. Good drainage facilitates the ready diffusion of oxygen to the root zone and escape of carbon dioxide from the root zone into the atmosphere. Several harmful gases also escape from the root zone into the atmosphere. The activity of aerobic organisms which influences the availability of nutrients such as nitrogen and sulphur to plants depends on soil aeration. If oxygen is present in the root zone, toxicity in acid soils due to excess iron and manganese is decreased. Drainage permits roots to grow deeper and spread wider thereby increasing the volume of soil from which nutrients can be extracted. The removal of excess water helps in warming of the soil quickly and optimum soil temperature permits timelines of the field operations. The provision a good drainage system permits the removal of excess salts if they are present in the soil or irrigation water and prevents their build up in the upper soil layers.

6. Measurement of Irrigation Water

Water measurement is necessary to plan the extent of area that can be irrigated. To avoid over or under irrigation, accurate measurement of irrigation water is essential. Excess application leads to deep percolation losses and leaching of nutrients while under supply leads to crop water stress.

Irrigation water can be measured in terms of units of volume or units of flow or depth. The units of volume commonly used are liter and cubic meter. The units of flow are the units volume expressed in units of time, i.e. liter per second, cubic meter per second (cusec).

6.1. Units of Measurement

The quantity of water that flows through a canal or structure in a period of time is known as flow or discharge and is expressed in m^3/ sec for large discharge and l/s for small discharges. 1m^3/ sec is equal to 1000 l/sec. The flow in irrigation system is also expressed as quantity/ volume of water used and volumetric flow rate.

Example 1.

When depth of irrigation water is, say, 10 mm, it can be expressed in meter.
Hence, one-meter depth of water = 1000 mm.
= 10/1000 m
= 0.01m
If this depth of water is applied in one hectare of land, volume/ quantity of water will be:
One hectare of land = 100 x 100 = 10,000 m^2
Volume/ quantity = Area x depth (m^3)
= 10,000 x 0.01 m^3
= 100 m^3One m^3 of water = 1000 liters, hence
= 100 x 1000 (liters)
= 100, 000 liters
The discharge, q in unit time could be computed on the basis ha of land:
q = V/t
q= [100,000/ (24*3600)] liters/ sec
=100,000/ 86400 l/sec
= 1.16 l/sec

6.2. Flow Measurement

6.2.1. Flow measuring devices used in surface irrigation

Various methods for measuring irrigation water are used and only few important that are day to day activities will be explained.

a) For large discharges the following device could be used:

- Weirs (thin-plate, rectangular, triangular or V-Notch, trapezoidal)
- Orifices

b) For small discharges and plot level irrigation the following devices could be used:

- Flumes (constructed and installed)
    - Parshall flume
    - Trapezoidal
    - WSC
    - Cutthroat
    - V-Notch
- Siphon tube

6.2.1.1. Parshall Flume

A flume is specially shaped channel section that is constructed or installed in open channels to obtain stable stage discharge relationship for flow measurement. It has three principal sections: converging or contracting section at upstream end, a constricted section or throat and a diverging or expanding section downstream.

The floor of the converging section is level both longitudinally and transversally. The width of the throat is used to designate the size of the flume. Only installation of parshall flume for free flow condition for all variation in flow is recommended. The discharge is obtained from various throat widths (Table 4).

Portable parshall flumes built of wood or galvanized sheet metal are used extensively for measuring irrigation flows in field channels in experimental fields.

Table 9. Free flow discharge values under different size of Parshall flumes

Head (cm)	Throat width (inches)				
	1	2	3	6	9
	Discharge (l/s)				
2	0.140	0.281			
3	0.263	0.526	0.772	1.496	2.504
4	0.411	0.822	1.206	2.357	3.889
5	0.581	1.162	1.705	3.354	5.471
6	0.771	1.541	2.261	4.473	7.232
7	0.979	1.957	2.872	5.707	9.155
8	1.205	2.407	3.532	7.047	11.231
9	1.446	2.889	4.239	8.489	13.448
10	1.702	3.402	4.991	10.027	15.801
11	1.973	3.943	5.786	11.656	18.281
12	2.258	4.513	6.621	13.374	20.885
13	2.557	5.109	7.496	15.177	23.605
14	2.868	5.731	8.408	17.062	26.440
15	3.191	6.377	9.358	19.027	29.383
16	3.527	7.048	10.342	21.070	32.433
17	3.875	7.743	11.361	23.188	35.585
18	4.234	8.460	12.413	25.38	38.837
19	4.604	9.200	13.499	27.643	42.186
20	4.985	9.961	14.616	29.976	45.630
21	5.376	10.744	15.764	32.379	49.167
22		11.547	16.942	34.848	52.794
23			18.151	37.384	56.510
24			19.389	39.984	60.312

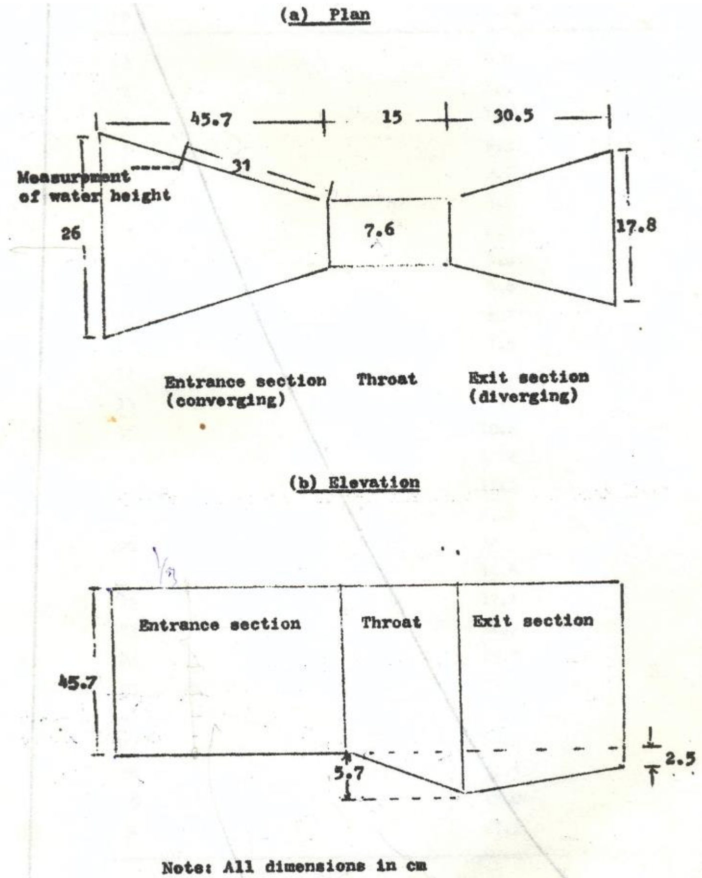


Figure 17. Typical features of a 3-inch Parshall flume

Discharge measurement

Example 2: Irrigation water measurement using 3-inch Parshall flue for net irrigation application of 45 mm, 60mm and 75 mm, the gross irrigation application at 60% application efficiency will be 75 mm, 100 mm and 125 mm depth of water.

Farm size: 10 m by 10 m = 100 m^2

Time (T) require to irrigate 75, 100 and 125 mm is computed from:

$$T = \frac{(A * drz)}{(6 * q)}$$

where T is time in munites; A is area of farm in m2; d is depth of gross irrigation requirement in cm and q is the discharge of Parshall flume at particular head in l/sec.

Table 10. Flow rate and time required to irrigate using Parshall flume

Head Reading (cm)	**q , Discharge (l/s)**	**T, Time Required (min.) = A*drz/6*q**		
		Drz = 7.5 cm	Drz = 10.0 cm	Drz = 12.5 cm
3	0.772	161.9	215.9	269.9
4	1.206	103.6	138.2	172.7
5	1.705	73.3	97.8	122.2
6	2.261	55.3	73.7	92.1
7	2.872	43.5	58.0	72.5
8	3.532	35.4	47.2	59.0
9	4.239	29.5	39.3	49.1
10	4.991	25.0	33.4	41.7

6.2.1.2. V-notch

The triangular (V-notch) thin plat weir is an accurate flow measuring device for flows less than 30 l/ sec. It is also as accurate as other thin plate measuring devices for measuring flows from 30 to 300l/sec. The triangular weir should be installed so that the minimum distance from channel bank to weir edge is at least twice the head on the weir. The distance from the bottom of the approach channel to the point of weir notch should be at least twice the head on the weir.

Table 11. Discharge values for 90° triangular-notch weirs with complete contraction

Head (m)	m3/s	Head (m)	m3/s	Head (m)	m3/s
0.05	0.00083	0.235	0.037	0.42	0.1577
0.055	0.00097	0.24	0.0389	0.425	0.1626
0.06	0.00124	0.245	0.041	0.43	0.1673
0.065	0.00152	0.25	0.0431	0.44	0.1772
0.07	0.00179	0.255	0.0543	0.445	0.1823
0.075	0.00207	0.26	0.0476	0.45	0.1874
0.08	0.00248	0.265	0.05	0.455	0.1926
0.085	0.0029	0.27	0.0523	0.46	0.198
0.09	0.00331	0.275	0.0549	0.465	0.2034
0.095	0.00386	0.28	0.0573	0.47	0.2089
0.1	0.00442	0.285	0.0599	0.475	0.2146
0.105	0.00497	0.29	0.0625	0.48	0.2202
0.11	0.00552	0.295	0.0653	0.485	0.226
0.115	0.00621	0.3	0.068	0.49	0.232
0.12	0.0069	0.305	0.0709	0.495	0.2379
0.125	0.00759	0.31	0.0738	0.5	0.244
0.13	0.00842	0.315	0.0769	0.505	0.2501
0.135	0.00925	0.32	0.0799	0.51	0.2563
0.14	0.0101	0.325	0.0831	0.515	0.2626
0.145	0.011	0.33	0.0864	0.52	0.2691
0.15	0.012	0.335	0.0897	0.525	0.2756
0.155	0.0131	0.34	0.063	0.53	0.2822
0.16	0.0141	0.345	0.0965	0.535	0.2835
0.165	0.0153	0.35	0.1001	0.54	0.2957
0.17	0.0164	0.355	0.1036	0.545	0.3026
0.175	0.0177	0.36	0.1074	0.55	0.3095
0.18	0.0189	0.365	0.1111	0.555	0.3167
0.185	0.0203	0.37	0.115	0.56	0.3239
0.19	0.0217	0.375	0.1158	0.565	0.3312
0.195	0.0232	0.38	0.1228	0.57	0.3385
0.2	0.0247	0.385	0.127	0.575	0.346
0.205	0.0262	0.39	0.131	0.58	0.3536
0.21	0.0279	0.395	0.1354	0.585	0.3613
0.215	0.0295	0.4	0.1397	0.59	0.369
0.22	0.0313	0.405	0.1441	0.595	0.3769
0.225	0.0331	0.41	0.1485	0.6	0.3849
0.23	0.0351	0.415	0.153		

The point at which the depth measurement of water flowing is four times the head H.

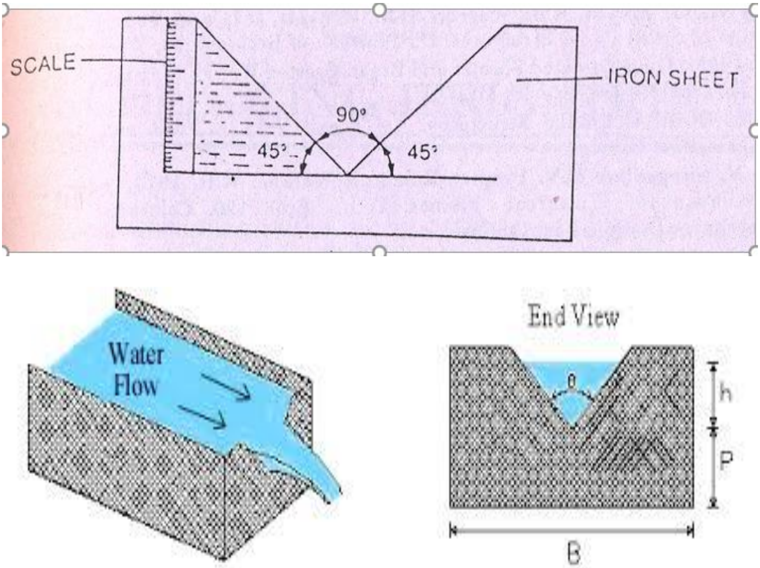


Figure – V-notch

The generally accepted formula is:

$$Q = 1.38\ H^{2.50}$$

where, Q is discharge in m^3/s and H is difference between the crest and the water surface at point upstream from the weir at a distance of four times the maximum head on the crest (m).

Example 3: Irrigation water measurement using V-notch for application of 75 mm, 100 mm and 125 mm depth of water**.** For same farm size as in parshall flume, Time require to irrigate 75, 100 and 125 mm is computed from T = (A * drz)/ (6 * q).

Table 12. Flow rate and time required to irrigate using V-notch

Head		Discharge		Time required (min.) = (A * Drz)/(6*q)		
Meter	Cm	m^3/sec	l/s	Drz = 7.5	Drz = 10.0	Drz = 12.5
0.050	5.0	0.00083	0.83	150.6	200.8	251.0
0.055	5.5	0.00097	0.97	128.9	171.8	214.8
0.060	6.0	0.00124	1.24	100.8	134.4	168.0
0.065	6.5	0.00152	1.52	82.2	109.6	137.1
0.070	7.0	0.00179	1.79	69.8	93.1	116.4
0.075	7.5	0.00207	2.07	60.4	80.5	100.6
0.080	8.0	0.00248	2.48	50.4	67.2	84.0
0.0850	8.5	0.0029	2.90	43.1	57.5	71.8
0.090	9.0	0.00331	3.31	37.8	50.4	62.9
0.095	9.5	0.00386	3.86	32.4	43.2	54.0

6.2.1.3. Siphon tube

Siphon tubes are used to remove water from a field channel and distribute it over a field through furrows, borders or basins and are also used to measure the rate of flow into these distribution systems. These tubes generally made of plastic pipes, are usually formed to fit a half cross section of the field supply channel. Rigid plastic (PVC) siphon pipes of internal diameter 6.6 and 4.2 cm are available commercially in the country. Further clear flexible plastic tubes of internal diameter 2.4 cm are also used as syphon. Flow into individual basins, borders and furrows can be easily controlled by adjusting the head as well as the number of siphons.

Example 4: Irrigation water measurement using siphon for application of 75 mm, 100 mm and 125 mm depth of water**.** For same farm size as in the other measurinf devices (parshall flume and v-notch), Time require to irrigate 75, 100 and 125 mm is computed from T = (A * drz)/ (6 * q).

Table 13. Flow rate and time required to irrigate using siphon

Head (cm	q (l/sec)	Time required (min), T = (A * Drz)/ (6 * q))		
		Drz = 7.5	Drz = 10.0	Drz = 12.5
4	0.8	156.3	208.3	260.4
6	0.98	127.6	170.1	212.6
8	1.13	110.6	147.5	184.4
10	1.26	99.2	132.3	165.3
12	1.39	89.9	119.9	149.9
14	1.5	83.3	111.1	138.9
16	1.6	78.1	104.2	130.2
18	1.7	73.5	98.0	122.5
20	1.79	69.8	93.1	116.4
22	1.88	66.5	88.7	110.8

Table 14. Discharge through siphon under varying heads

Head cm	Discharge l/s internal siphon diameter		
	6.6 cm	4.2 cm	2.4 cm
4	1.98	0.80	0.24
6	2.42	0.98	0.29
8	2.80	1.13	0.34
10	3.13	1.26	0.38
12	3.43	1.39	0.42
14	3.70	1.30	0.43
16	3.96	1.60	0.48
18	4.20	1.70	0.51
20	4.43	1.79	0.54
22	4.64	1.88	0.56
24	4.85	1.96	0.59
26	5.05	2.04	0.61
28	5.24	2.12	0.63
30	5.42	2.19	0.66
32	5.60	2.26	0.68
34	5.77	2.33	0.70
36	5.94	2.40	0.72
38	6.10	2.47	0.74
40	6.26	2.53	0.76
42	6.42	2.39	0.78
44	6.57	2.65	0.80
46	6.71	2.71	0.81
48	6.86	2.77	0.83
50	7.00	2.83	0.85

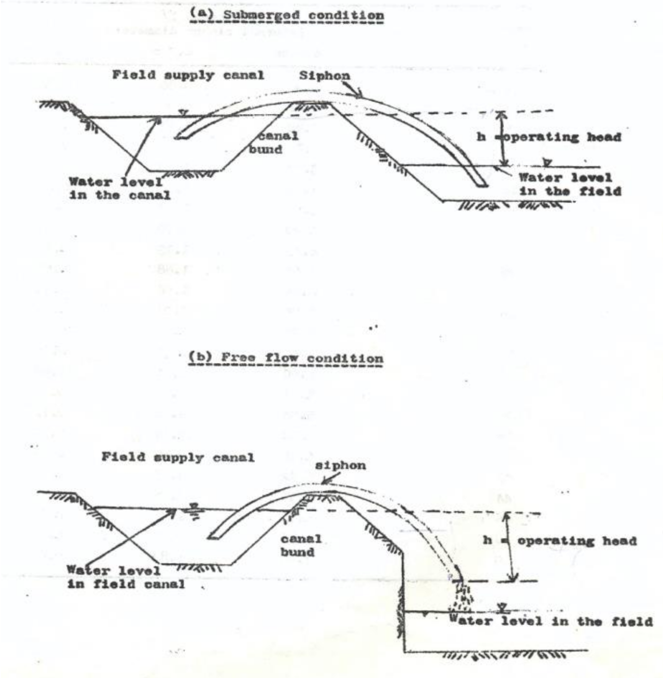


Figure 18. Siphon operating under submerged and free flow conditions

6.2.2. Measuring irrigation water under pressurized irrigation

6.2.2.1. Sprinkler irrigation

A sprinkler irrigation system consists of a pipe network, through which water moves under pressure before being delivered to the crop via sprinkler nozzles. The sprinkler application rate should not exceed the basic soil infiltration rate (Table 8).

Example 5: Under typical clay loam soil the basic infiltration rate was 20 mm/hour. The sprinkler had application rate 15 mm/hour. The application efficiency of sprinkler irrigation is about 80%. The net irrigation application was 45 mm, 60 mm and 75 mm. The gross irrigation application will be about 56 mm, 75 mm and 94 mm. Hence, the time taken to irrigate the net irr 56 mm, 75 mm and 94 mm depth of water will be:

T= Depth of irrigation

Sprinkler rate of application
= 56 mm/ 15mm/hr
= 3 hours and about 44 minutes

Thus, the time taken to irrigate 75 mm and 94 mm depth of water will be 5 hrs, and 6 hrs and about 16 minutes, respectively**.**

6.2.2.2. Drip irrigation

Drip irrigation applies small drops of irrigation water directly onto the soil near to the plant. The water is distributed under low pressure through a pipe network. Under drip irrigation, not all area is wetted. Hence, irrigation application under drip irrigation is partially wetted. Hence, irrigation application efficiency for drip irrigation is mostly assumed about 90% and for medium soil/ clay loam soil the wetted area is assumed about 60%.

Example 6: The net irrigation application of 45 mm, 60 mm and 75 mm under drip irrigation with 90 % application efficiency, the gross irrigation application will be about 50 mm, 67 mm and 83 mm.

Assumption:

Crop: Tomato
Spacing: Row = 1.0 m and plant to plant = 30 cm
Area is same like that of surface and sprinkler irrigation
Emitter spacing: 0.30 m
Emitter discharge, q: 2 l/h
Number of laterals: 10
Number of emitters per lateral: 10/0.30 = 33
Total number emitters: 10 * 33 = 330
Total discharge, Q: 330 * 2 = **660 l/h**

Volume of irrigation = 100 m2 * 50/1000 = 100 * 0.05 = 5 m^3
= 5 * 1000 litres
= 5000 litres

Wetting area is 60 % and hence the total volume of water needed to apply = 5000 * 0.6
= 3000 litres

Time taken to irrigate 3000 liters of water in 100m^2 area = 3000/660 = **4 hours and 32 minutes and 44 seconds.**

Same way to irrigate the gross irrigation application of 67 mm and 83 mm will be:
Volume (liters) = 100 * 67 = 6700
W,a, = 60%, hence 6700*0.6 = 4020 litres
Time taken to irrigate 4020 liters = 4020/660 = **6 hrs and about 5 minutes**
Volume (liters) = 100 * 83 = 8300 liters
W,a, = 60%, hence 8300*0.6 = 4980 litres
Time taken to irrigate 4980 liters = 4 980/ 660 = **7 hrs 32 minutes and about 44 seconds**